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LABOR SAVING AT LIMESTONE QUARRIES

BY

OLIVER BOWLES

WASHINGTON
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PREFACE.

In accordance with a cooperative agreement between the United States Geological Survey, the Bureau of Standards, and the Bureau of Mines, a study of various phases of the stone-quarrying industry was begun by the Bureau of Mines in 1914. As a result of these investigations the Bureau of Mines has issued the following publications: "Safety in Stone Quarrying," Technical Paper 111, 1915; "The Technology of Marble Quarrying," Bulletin 106, 1916; "Sandstone Quarrying in the United States," Bulletin 124, 1917; and "Rock Quarrying for Cement Manufacture," Bulletin 160, 1918.

The participation of the United States in the great war led the Bureau of Mines to concentrate its activities on such phases of the mining and quarrying industry as were most essential to military effectiveness. In quarrying, as in many other industries, labor shortage constituted a grave problem. As a result of the formation of a great Army and Navy, and the growth of industries for supplying them with munitions and other necessaries, many men both skilled and unskilled were taken by enlistment or by the selective draft. In addition, the formation of a regiment (the Twenty-eighth Engineers) consisting entirely of skilled quarrymen further reduced the available labor supply in this most necessary class of workers.

As the situation became more and more acute the necessity for conserving labor in quarries by every possible means led Mr. Bowles to prepare a paper designed to assist in some measure in relieving the shortage in those branches of the limestone-qarrying industry that were deemed indispensable to the military program. In order to bring to the immediate attention of quarrymen, the suggestions contained in this paper, a limited number of copies were mimeographed as No. 1 of a War Minerals Investigations Series, and sent to quarry operators early in September, 1918.

With the cessation of hostilities on November 11, 1918, the suggestions contained in this pamphlet could, from a purely military standpoint, render no further service. It is not probable, however, that with the return of peace the problem of labor shortage in quarries will be speedily solved. With the prospect of an increased industrial development the problems of saving labor, of improving labor conditions, and of conserving the lives and health of quarrymen are pertinent in peace as in war. It is believed therefore that the distribution of this paper as a regular Bureau of Mines publication will be of permanent service to the limestone-quarrying industry.

CHARLES L. PARSONS,
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LABOR SAVING AT LIMESTONE QUARRIES.

By Oliver Bowles.

INTRODUCTION.

Limestone is a raw material essential to many industries. Any serious curtailment in the output would therefore hamper or suspend certain industries, some of which are of great military importance.

The unprecedented demand for iron and steel occasioned by the war has developed maximum activity at the blast furnaces in the United States. As limestone is required for smelting the great bulk of our iron ores, the quarrying of blast-furnace flux is an industry essential to the successful prosecution of war. The heavy demand for fluxing limestone, combined with an increasing difficulty in obtaining sufficient quarry labor, has resulted in a condition that demands relief. Hence, the Bureau of Mines is endeavoring to disseminate whatever information it may possess that will in any way assist quarrymen in their efforts to produce a maximum of rock with a minimum of labor. The purpose of this pamphlet is, therefore, to direct the attention of quarrymen to the most successful and efficient labor-saving methods and machines. Although many such are now in successful use, there are few companies that can not in some way modify their methods or equipment so as to conserve labor.

The writer has visited a number of fluxing-limestone quarries for the express purpose of observing labor-saving devices, and, in connection with his investigation of quarrying during the past four years, has obtained information relating to them. This pamphlet mentions only those methods and types of equipment that have been tried and approved by quarry operators.

FORMER ADEQUACY OF LABOR SUPPLY.

The demand for labor in limestone quarries has in past years been adequately met in most localities, especially in the Southern States. In fact, labor has in many instances been more readily obtainable than capital. This condition is reflected in the quarry equipment, for where capital has been more difficult to obtain than labor the tendency has been to employ only the most necessary mechanical equipment and wherever possible to use hand methods.

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INTRODUCTION OF MECHANICAL EQUIPMENT.

The tendency to employ hand labor rather than machines has certain disadvantages, and of late years, especially in large quarries, hand methods have been largely superseded by mechanical means. At most quarries the substitution was not made because there was a pronounced shortage of labor but because the new methods were quicker, cheaper, and promoted a rapid and decided increase in output.

When labor is cheap and plentiful the advantages of mechanical equipment, particularly in small quarries, are questioned by many operators. In large quarries the advantages of mechanical equipment are generally recognized. The adoption of such equipment has, however, been slow in many places. This slowness has resulted from various causes, the chief of which are the conservatism of operators, a lack of information on modern equipment, and the lack of capital.

QUARRYING AN ESSENTIAL INDUSTRY.

Although it is difficult to judge properly the relative military importance of various industries, it is comparatively easy to select those industries that contribute definitely and materially to the war strength of the Nation. Various branches of limestone quarrying fall in the latter class. Many quarries produce stone for concrete aggregate, for cement or lime, or for road material, all of which contribute more or less directly to the military program.

One branch of quarrying, however, is directly associated with an industry of vast military importance. The heavy demand for iron and steel occasioned by the war keeps blast furnaces running at maximum capacity. The increased output of iron necessarily means a larger demand for fluxing limestone. According to statistics compiled by the United States Geological Survey the production of blast-furnace flux in the United States during 1916 amounted to 23,603,508 tons, valued at $13,936,882, an increase of 24 per cent in quality and 44 per cent in value as compared with 1915. The increase during 1917 evidently continued at about the same rate. In August, 1918, a technical journal said that the production of fluxing limestone had then reached 120,000 tons daily. The larger demand for flux is occasioned partly by the larger output of iron and partly by the wider use of siliceous ores that require a high proportion of flux. As an adequate supply of limestone for flux is absolutely necessary in iron smelting, limestone quarrying ranks among the most essential industries. Hence, it is obvious that every precaution should be taken to insure such a supply.

A pronounced shortage of limestone would paralyze the iron-smelting industry no less surely than a shortage of fuel or of ore.

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It is wise, therefore, to consider carefully any circumstances that may tend to curtail production materially, and to take whatever steps may seem advisable to overcome every obstacle.

THE PRESENT DEMAND FOR LABOR.

During 1917 and 1918, a new factor has been felt in all the industries of this country. The creation of a great Army and Navy, the development of industries to furnish the fighting men with food, clothing, munitions and equipment, the necessity for supplying our allies with war material, and the building of an immense merchant fleet, have combined to increase greatly the demand for labor, and this demand will probably become more and more acute as the military strength of the country develops. Evidently, therefore, a shortage of labor is one of the serious problems, if not the most serious problem, that confronts limestone-quarry operators at present.

NEED OF LABOR-SAVING DEVICES.

The demand for a greatly increased production of fluxing limestone, combined with a labor shortage, creates an acute situation that demands relief. One obvious method of relief is to substitute mechanical equipment for hand labor. Fortunately, many such substitutes are not only known but have passed the experimental stage, and are now in successful operation in many places. Labor may also be conserved by simplifying quarry methods, by more efficient blasting, and by various improvements.

DEFINITION OF LABOR SAVING.

Labor-saving devices and methods include all quarry equipment and quarry methods the employment of which tends to reduce the labor required for a given output. Such saving of labor is accomplished by mechanical devices performing work formerly done with hand tools, by equipment that simplifies quarry methods and eliminates unnecessary operations, by methods or plans that utilize every natural condition to best advantage, and by conducting quarry work so that time is not wasted in idleness or in unprofitable employment.

Many labor-saving devices are in the form of mechanical equipment, machines controlled by a few men doing as much work as can be done by a large number of men unassisted by machines. Other labor saving is effected by the use of simple and direct quarry methods. Quarry operations should be planned so as to eliminate all methods that necessitate unnecessary labor. Thus excessive rehandling of material, complexity of transportation systems, and loss of time through the conflict of different operations should be avoided.

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Where any of these can be accomplished by modification of method, involving no heavy expense in the purchase of new equipment, the labor saving is of a type that demands special encouragement.

DIFFICULTIES IN PURCHASING NEW EQUIPMENT.

Objections to the purchase of new mechanical equipment at this time are: The shortage of supply from the need of machine shops making war material, the heavy demand for iron and steel, and the high cost of machinery. Many operators, however, are fully convinced that certain types of quarry machinery offer advantages enough to encourage their purchase even under the present unfavorable conditions.

LABOR-SAVING METHODS AND DEVICES.

Having pointed out the need of labor-saving devices that is put on quarrymen by the extraordinary conditions of the war, the writer now calls attention to specific types of labor-saving equipment and discusses those quarry conditions and methods that favor economy of labor.

Many of the methods and types of equipment discussed on the following pages are applicable only to quarries of considerable size; for operators with small capital would scarcely be justified in purchasing expensive equipment. However, a smaller and simplified modification of the elaborate equipment designed for large quarries could probably be substituted to advantage for hand methods in many small quarries.

PROPER PLANNING OF A QUARRY.

Methods of opening a quarry may have a direct bearing on the economy of labor in development. The depth of overburden to be removed should be carefully noted and an effort made to develop the quarry in a direction that requires the minimum of stripping.

All rock structures should be carefully considered, for their presence may greatly affect the ease of rock removal. At one locality in New York, for example, the limestone beds dip about 4°, and the quarry was opened so that development was down the dip. As a consequence, water accumulates at the working face after every heavy rain, causing a temporary suspension of work with consequent loss of labor. Had the quarry been opened so that development proceeded in the opposite direction, the water would have drained away and no accumulation at the face would have been possible.

Planning a quarry so as to utilize rock structures to best advantage may greatly economize labor. Where limestone lies in approximately horizontal beds the utilization of an open-bed plane for the

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quarry floor, or a bench floor, not only makes blasting easier, but the smooth surface that results requires little or no grading or ballast for tracks, and the labor needed in track-laying can be reduced to a minimum. A smooth floor also facilitates the loading of rock.

The quarry, crusher, and storage bin should be so situated that transportation may be simple and direct, and the force of gravity should be utilized wherever possible. This matter is considered in greater detail under the heading "Transportation."

CARE IN SEPARATING OVERBURDEN AND ROCK.

NEED OF REMOVING OVERBURDEN.

Limestone quarried for blast-furnace flux must be as free as possible from siliceous impurities. Commonly the permissible silica content is limited to 2 per cent. As large a proportion as possible of the quarry overburden, which may comprise clay, sand, gravel, bowlders, or mixtures of these materials, all containing a large percentage of silica, must therefore be separated from the rock.

SELECTION OF STRIPPING METHODS.

The removal of overburden is accomplished in many different ways, the variations in method depending greatly on quarry conditions. The amount of overburden to be handled may be a few inches or 25 or 30 feet. Obviously methods employed for the removal of a few inches of foreign material would not be applicable for the removal of a depth of several feet. Stripping methods should be governed by the character and depth of the overburden, and also by the nature of the rock surface, by the convenience of the dumping ground, by water supply and drainage, and by the amount of capital available for stripping equipment.

OVERBURDEN SHOT DOWN WITH ROCK.

Operators of quarries in rock deposits with overburden a few inches thick may be justified in shooting down the overburden with the rock, and in separating rock and waste material subsequently. Where seams or erosion cavities are filled with clay, sand, or gravel, the difficulty of removing the waste material before rock blasting may render it necessary to blast the rock and the waste together, and to separate the siliceous material from the good limestone at a later time by either of two methods.

By the first method the rock fragments are loaded on cars by hand, and accumulations of débris are loaded in the same way. For small quarries such procedure may be justified, but with a labor shortage

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the method is too slow and laborious to be recommended for quarries of considerable size.

The second method is in common use at the larger quarries. The rock fragments and the waste material are loaded with a steam shovel, a method that is economical of labor, and the good rock and waste are separated by screening or by washing and screening. As regards labor saving, this method is greatly to be preferred. One objection to the method is the waste of finer rock fragments that pass through the screens with the débris, but this waste may be partly prevented by screening the rock to various sizes and discarding only the finest material.

OVERBURDEN REMOVED PRIOR TO QUARRYING.

Although the shooting down of rock and overburden together and their subsequent separation by sorting, screening, or washing may be justified under some circumstances, the removal of overburden prior to rock blasting offers definite advantages.

As they occur naturally serviceable rock and waste material are as a rule distinct and are separated by a well-defined boundary. An exception to this rule is the occurrence of clay seams or pockets in the rock ledge. Where considerable débris is originally unmixed with the rock, it is obviously a poor policy to mix rock and waste in blasting and to separate them subsequently. It involves unnecessary handling of waste, and in rainy seasons the presence of sticky clay with rock impedes work and renders separation difficult. A better plan is to remove overburden as completely as possible before blasting the ledge.

Various methods in common use for the removal of stripping have been described in other publications of the Bureau of Mines.[a] This paper aims to give special consideration to labor requirements of each method.

LABOR REQUIREMENTS OF DIFFERENT STRIPPING METHODS.

Loading waste material into dump carts or cars with hand tools is doubtless recognized by most quarrymen as involving the most prodigal use of labor per ton of material removed of any method in common use. Fortunately, it is not commonly employed except in very small quarries.

Where the overburden rests on a reasonably smooth rock surface and the dumping ground is near by, the employment of teams and scrapers instead of hand labor results in a pronounced saving. Where the waste must be moved a considerable distance the scraper

[a] Bowles, Oliver, Sandstone quarrying in the United States, Bull. 126, Bureau of Mines, 1917, pp. 26–33, and Rock quarrying for cement manufacture, Bull. 160, Bureau of Mines, 1918, pp. 37–42.

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loads may be dumped through an opening into wagons on a depressed roadway, the soil being thus handled in two operations. Under such circumstances wheel scrapers are to be preferred, for thus a single operation will suffice, and such simplification reduces the labor requirement.

A drag-line scraper alone has been used effectively where conditions are favorable, and a drag-line scraper used in conjunction with dump cars, as described in Bulletin 160,[a] may be used to advantage. By either method the heaviest burden of the work is accomplished by machinery, and the labor requirement is not high.

The most popular stripping equipment for large quarries is the steam shovel. It requires a small gang of men, and when properly handled and well supplied with cars can load a great mass of material in a day. Efficient service depends on strong mechanical construction, adequate care, and the employment of a skilled runner. Inefficient work by steam shovels usually results from inadequate car service for removing loaded material rather than from improper handling of the steam shovel itself. However, this subject is considered under "Transportation."

Although the first cost of a steam shovel is high, with proper care the cost of maintenance is not excessive. Where the rock surface is fairly uniform and level a steam shovel is probably the best equipment for loading a considerable thickness of overburden.

A stripping conveyer to be used with a steam shovel is illustrated and described in a former publication.[b] Such equipment can not be generally employed for it is applicable only to quarries where the overburden may be conveniently dumped in the pit formed by removing the good rock.

With adequate water supply, proper drainage, and sufficient area for waste disposal, hydraulic stripping is probably the most economical of labor of all methods in common use. Two men at the pumping station and two handling the nozzle can wash down a great mass of débris in a day. The rate of removal depends on the size of the nozzle, the available water pressure, and the consistence of the soil. The rate of progress may be retarded if the overburden is hard, for then boring it with a soil auger and blasting with powder may be necessary. Moreover, the presence of numerous bowlders may render hydraulic stripping difficult.

As labor is the chief item of cost in stripping, the cost per cubic yard is a fair indication of the relative labor requirements of various processes. The following figures represent minimum costs noted by the writer during field investigations and may be of interest in

[a] Bowles, Oliver, Rock quarrying for cement manufacture, Bull. 160, Bureau of Mines, 1918, pp. 37–38.

[b] Bowles, Oliver, Work cited, pp. 39, 40.

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this connection. Hand-shovel and dump-cart method, 30 cents a cubic yard; steam shovel with cars hauled by dinkey engine, 16 cents; steam shovel and stripping conveyer mentioned above, 3 cents; drag-line scraper (to loading platform only), 3 cents; hydraulic stripping, 3 cents.

LABOR SAVING IN DRILLING.

LABOR REQUIREMENTS OF DRILLS COMMONLY USED.

For multiple-bench or snake-hole quarrying, tripod drills are generally employed, though of late years large hammer drills have been used successfully by many operators. For ledges not exceeding 40 feet in thickness, wagon drills have proved successful in a few localities. For single-bench quarrying of a quarry face 25 feet or more high, churn drills are now widely used.

Tripod drills require two men each, a runner and a helper, except that sometimes one helper is deemed enough for two drills. Hammer drills require no helpers, and are therefore more economical of labor than tripods. Wagon or churn drills usually require two men each, though some electrically operated churn drills employ only one man each.

The churn drill, although a comparatively recent type of equipment in limestone quarries, is rapidly gaining favor and is in successful use at a great many places. Although there are conditions under which it is claimed that other types of drills render better service, yet as regards labor requirements the churn drill has the advantage of doing the work of four or five tripods or hammer drills with no greater labor than is required for a single tripod. A quarry operator in Pennsylvania claims that one churn drill, one tripod, and one hammer drill accomplish as much as was formerly done in the same quarry with five tripods and three hammer drills. On a conservative estimate of the labor requirement, the old method would require 11 men and the new method 5.

One Texas operator reports that when he employed five tripod drills his plant was frequently shut down through lack of rock; and when one churn drill was substituted for the five tripods the plant was continually supplied, and the drill was used part of the time only.

As in stripping, the relative direct cost of drilling with different types of equipment is a fair measure of their relative labor requirement. Russell,[a] in an article entitled "Loading and shooting big blast holes," estimates that the average cost of steam tripod drilling is about 8 cents a cubic yard of rock quarried, while the average cost

[a] Russell, S. R., Blast-hole drilling with Keystone cable drill, published by Keystone Driller Co., 1915, p. 10.

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of churn drilling is about 2 cents. These figures indicate that the churn drill promotes labor economy.

When churn drills are employed, not only is there a decided saving of labor in the actual drilling, but there may be a marked saving of labor elsewhere. When tripod drills are employed in deep quarries, the face must be worked in a series of benches. Bench cleaning is therefore necessary, and tracks must be moved frequently. One quarryman reports that the introduction of churn drills released 15 men formerly employed at work rendered unnecessary by the introduction of the new equipment.

LABOR SAVING IN PRIMARY BLASTING.

WASTE OF LABOR THROUGH INEFFICIENT BLASTING.

In the actual loading, tamping and wiring of charges in drill holes there is little variation of method, and relatively little labor is involved; hence no appreciable amount of labor can be saved by modifying the mechanical processes connected with blasting.

However, efficiency in blasting has a direct bearing on the amount of labor required subsequently. Improper arrangement of drill holes, imperfect balancing of charges, or the use of too strong or too weak an explosive may result in a very inefficient blast, and as a consequence the loading of rock may be greatly hampered. In fact there is no other department of the quarry in which inexperience or lack of judgment may in a brief period occasion more disastrous consequences. This is particularly true where many large blasts are fired simultaneously in deep churn-drill holes, for the mass of rock thrown down may occupy the rock loaders for a period of several weeks or even months. If the rock is imperfectly shattered, or improperly thrown down excessive secondary blasting may be required, and the loading may be slow and difficult throughout the entire period. Hence it is false economy, both of money and labor, to employ inexperienced men as blasting foremen.

CONSERVATION OF LABOR THROUGH EFFICIENT BLASTING.

If on the other hand blasting is done by an experienced man of good judgment, the subsequent operations may be greatly simplified. If the rock is thoroughly shattered, little labor is required for secondary blasting, and if the rock fragments are thrown down in a way that permits easy handling, loading may be done rapidly and with minimum effort.

EMPLOYMENT OF BLASTING EXPERTS.

A realization of these facts has led some operators to engage the services of blasting experts who are not permanent members of any

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quarry organization but travel from quarry to quarry as their services are desired. Such an expert, in accordance with the judgment gained by long experience, supervises the arrangement and spacing of drill holes, selects the explosive, proportions the charge for each hole, carefully inspects or tests all connections, and fires the charge. The efficiency of the results usually obtained amply justifies the employment of such experts.

LABOR SAVING IN SECONDARY BLASTING.

FACTORS GOVERNING SECONDARY BLASTING.

The labor required for secondary blasting depends on various factors, the chief of which are the efficiency of the primary blasting, the physical character of the rock, the method of rock loading, and the method of secondary blasting. These factors are considered in the following paragraphs.

EFFICIENCY OF PRIMARY BLASTING.

If the rock ledge is thoroughly shattered by the primary blast, little secondary blasting may be required. If, however, the primary shot merely fractures the ledge and produces many large solid blocks, much secondary blasting may be needed to reduce the blocks to convenient size. Hence, it is evident that the extent of secondary blasting depends in large measure on the efficiency of primary blasting. As pointed out in a previous paragraph, the employment of an expert blaster for primary shots tends to eliminate much of the secondary blasting.

PHYSICAL CHARACTER OF ROCK.

Schistose rock is usually shattered effectively by the primary blast. Where the schistosity is duly moderate the rock has a tendency to split in long thin slabs. Such splitting is known among quarrymen as "slab cleavage." In most limestone quarries, however, the rock is massive and tends to break into more or less cubical blocks. Such rock is said to possess "cubical cleavage." Where steam-shovel loading is employed, rock having slab cleavage requires less secondary blasting than that with cubical cleavage, for a rock crusher will accommodate a larger mass in the form of a long thin slab than in that of a cube. Schistosity, therefore, tends to reduce the need of secondary blasting. In some of the schistone cement-rock deposits of the Lehigh district of Pennsylvania, the rock is so thoroughly shattered by the primary blast that little or no secondary blasting is required. Few quarries for the production of blast-furnace flux are of this type as the rock is usually massive.

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Where vertical open seams 6 to 8 feet apart cut the rock the primary blast tends to push out large solid masses that require excessive secondary blasting. A method of dealing with such an unfavorable condition is discussed in detail in Bulletin 160[a] in which it is pointed out that at least one of the blast holes for the primary shot should be located in each rock mass between seams, for thereby each mass is shattered. On the other hand, any large mass that is not penetrated by a drill hole is simply pushed out. It is evident, therefore, that the amount of secondary blasting required in connection with unsound rock ledges is largely dependent on the skill employed in primary blasting.

The toughness of the rock is also an important factor in this connection. Tough rock with few seams or bed planes tends to break into large cubical masses requiring maximum secondary blasting. The proper method of dealing with such rock can usually be determined only by experience. By varying the diameter, spacing, and burden of primary drill holes, or by varying the amount or grade of the explosive the blast foreman may be able to arrive at a combination that will promote effective shattering and thereby reduce the secondary blasting needed.

METHODS OF LOADING ROCK.

If the rock is loaded by hand the fragments must be small enough for one man to handle, or must at least be small enough to be easily sledged to one-man size. Consequently, if many large blocks result from the primary blast, much secondary blasting may be necessary where hand loading is employed.

If a steam shovel is used for rock loading, especially if the shovel is equipped with a dipper having a capacity of 3 to 4 cubic yards, large rock masses may be loaded and secondary blasting may be reduced to a minimum.

LABOR SAVING IN LOADING ROCK.

NEED OF EFFICIENT METHODS.

Rock loading is an important department in the quarrying of limestone; in fact many quarries require more labor for this than for any other work. In some localities, the cost of loading is one-third to one-half of the total cost of quarrying. Therefore, special efforts should be made to conserve labor in loading.

LOADING BY HAND AND WITH POWER SHOVELS.

Two distinct methods of loading rock are in common use. In some quarries the rock is shattered by blasting into fragments that one man

[a] Bowles, Oliver, Rock quarrying for cement manufacture, Bull. 160, Bureau of Mines, 1918, pp. 50, 51.

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can handle, or to sizes that can be readily reduced to one-man size by sledging. These fragments are then loaded into cars by hand. In many quarries hand loading has been superseded by the use of power shovels driven by steam, electricity, or compressed air. The advantages and disadvantages of these two methods have been discussed in a former publication.[a]

For quarrying fluxing limestone the most obvious advantage in the hand-loading method is the ability of the hand loader to select desirable and to reject inferior material. Thus hand-loaded rock may be hand picked. Where steam shovels are employed such selection is not possible; if siliceous material is shot down with the rock it must be loaded with the rock and separated subsequently by screening or washing.

LABOR REQUIREMENTS OF HAND LOADING.

The tonnage of rock loaded by hand per man per day varies greatly in different localities. Thus in one of the largest fluxing quarries of the Birmingham district of Alabama the loaders average about 18 tons a day each, in a western Pennsylvania quarry they average only 15 tons a day, and in two eastern Pennsylvania quarries they average 25 and 30 tons, respectively, a day. An average of several quarries, some for the production of limestone for Portland cement and some for the production of limestone flux, is 20 tons per man per day. Thus a quarry producing 1,000 tons of rock a day requires an average of about 50 loaders.

LABOR REQUIREMENTS OF STEAM SHOVELS.

The labor needed for steam-shovel work varies as it depends on the size of the shovel employed and on the working conditions. In one eastern Pennsylvania quarry a small tractor shovel with a three-fourths-yard dipper requires a maximum of three men and loads a maximum of 400 tons a day. The quarry foreman claims that the shovel can accomplish as much work as 12 hand loaders, though ordinarily it does the work of seven or eight. A shovel of this type, therefore, saves the labor of four or five men on an output of 250 to 300 tons a day. In another Pennsylvania quarry it is claimed that two steam shovels employing 10 men in all load as much rock as 45 men by hand methods.

In one western New Jersey quarry a steam shovel employing three shovel men and four pit men loads 1,200 tons a day, or an average of 171 tons per man per day. In one eastern Pennsylvania quarry two steam shovels, requiring the services of a total of 16 men, load 1,000

[a] Bowles, Oliver, Rock quarrying for cement manufacture, Bull. 160, Bureau of Mines, 1918, pp. 118–124.

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tons a day, or an average of only 63 tons per man per day. Figures obtained at various quarries in widely separated localities indicate that an average of about 128 tons of rock per man per day is loaded by the use of steam shovels.

These figures show that a material saving of labor may be effected by the use of steam shovels for loading rock. Yet although steam shovels are now used in many quarries, hand loading is still employed in many others. Various objections may be raised to the employment of power shovels, but the saving of labor that may be had by their use should be carefully considered, and shovels should be adopted when practicable by operators who still use hand-loading methods. Although the first cost of steam shovel equipment has increased greatly, it is probable that the increase is not out of proportion to the higher wages paid to laborers.

LABOR SAVING IN ROCK TRANSPORTATION.

SIMPLE AND DIRECT TRANSPORTATION SYSTEMS.

A simple and direct system of transportation should be part of the plan for a new quarry. Ease of transportation depends greatly on the situation of the rock ledge, which preferably should be close to transportation lines and lie at a higher level. A shelf quarry with a floor higher than the crusher or other plant used in connection with the quarry represents the most favorable condition, for thus transportation may be accomplished by gravity and by a single operation. Usually the conditions are less favorable than this, so that more complex transportation systems may be required. Whatever the conditions may be, a single efficient system should be used and, if this is not possible, the fewest possible combinations of different systems of transportation should be employed. At one quarry the transportation of rock from the quarry face to the crusher involved the use of a horse, a cable incline, and a locomotive. Such a complication of systems necessitates too much labor.

UTILIZATION OF GRAVITY.

Gravity, when properly utilized, is an effective substitute for power in transporting rock and therefore it should be utilized wherever possible. A previous report [a] of the Bureau of Mines cites the use of gravity at a New Jersey quarry with such efficiency that transportation within the quarry for an average production of 1,200 tons of rock a day requires the services of one man only.

At one New York quarry, the rock is hauled to the crusher in cars by locomotives, all subsequent movements being assisted greatly by

[a] Bowles, Oliver, Work cited, p. 133.

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gravity. The plant is on a hillside; the crusher, screens, storage bin, and railway line for final haulage being at successively lower levels. Thus the movement of the rock is automatic and requires little or no supervision.

The substitution of gravity for man power offers many attractive possibilities when viewed with regard to the present labor shortage.

ADEQUATE ROLLING STOCK.

An adequate supply of rolling stock is essential for economy of labor. A shortage of cars or of locomotives is sure to result in frequent temporary delays with consequent loss in labor efficiency.

Cars should be strong enough to withstand the hard usage required in loading and unloading. Car breakage may tie up transportation, and any prolonged delay may retard other operations, such as loading and crushing. Furthermore, frequent repairs reduce the available car supply and increase the labor required in the repair shops. Some repairing is inevitable but the use of strong cars tends to reduce repairs.

Certain types of transportation equipment tend to conserve labor. By means of the central-control three-rail electric system now employed in certain large limestone quarries, several thousand tons of rock may be delivered from the steam shovel to the crusher daily with the employment of only two or three men. Aerial tramways and various types of cableways are for the most part automatic and hence require little labor.

ROADBEDS AND TRACKS.

Except where cable cars are employed, every effort should be made to eliminate heavy grades. Car haulage on such grades is wasteful of time and power. The maintenance of a firm roadbed and uniform gage also facilitate rapid and safe movement of trains. The trackage system for any quarry should be planned to cover the most convenient and direct routes.

Repairs for both tracks and rolling stock should receive immediate and careful attention. It is false economy of labor to reduce the normal number of repair men, for with defective equipment there is constant danger of accident and delay.

REHANDLING OF MATERIAL.

A fruitful source of wasted effort is the rehandling of material. Rock is commonly unloaded and reloaded unnecessarily, or dumped in places where undue labor is needed for its subsequent removal. At one quarry a small percentage of a type of rock necessary for

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plant operation is brought from a distance and mixed with the main supply of rock quarried at the plant; it is carried in hopper-bottom cars, dumped to the bottom of a 40-foot quarry pit, reloaded by hand into carts, hauled by mules to the foot of an incline, and lifted by cable to the crusher. Such excessive rehandling may be due to lack of equipment or to faulty plant design. In time of labor shortage, it is imperative that such faults be remedied by radical changes.

LABOR SAVING AT THE CRUSHER.

PROPER SIZE OF CRUSHER.

The size of the crusher used directly affects the labor required, not only for the actual crushing but also for other branches of quarry work. A prolific source of wasted effort is the use of a small crusher for rock loaded with a powerful steam shovel. The attempt is commonly made to substitute steam shovels for hand loading and yet retain the small crushers usually employed for rock loaded by hand. Such a combination of a massive loading apparatus with a small crusher has a twofold effect on the labor requirement.

In the first place, much labor may be required to force the large rock fragments into the crusher. At one quarry a No. 9 gyratory crusher is employed to handle rock loaded with a No. 60 Marion steam shovel. Four men were employed to force the rock fragments into the crusher, and the total output averaged only 400 tons a day. Obviously, the rock could be handled with greater facility and with fewer movements by a crusher having a wide mouth.

In the second place, the use of a small crusher increases the labor required for handling the rock in the quarry. With a large crusher, blocks of the full capacity of the steam-shovel dipper can be loaded, but if the crusher has a narrow opening all large blocks of stone must be reduced to convenient size. Such blocks must consequently be shattered ahead of the steam shovel or be set aside and broken subsequently by blasting. Evidently such processes demand additional labor.

With steam-shovel loading, therefore, large crushers are of distinct advantage in conserving labor.

TYPE OF CRUSHER.

Opinion is divided as to the best type of crusher. Gyratory crushers are popular and are in common use. Single or double roll crushers have the advantage of wide mouths that are not readily obstructed by blocks of stone. A jaw crusher fed by a traveling apron is an effective labor saver.

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REMOVAL OF JAMMED BLOCKS.

Blocks of stone often jam in the crusher mouth, particularly at gyratory crushers. If adequate facilities for removing such blocks are not provided, much time and labor may be wasted. Attempts to loosen jammed blocks with a bar or a sledge may so delay the crusher that other related operations, particularly transportation, may be temporarily suspended. Hence it is wise to equip rock-crushing plants with mechanical devices, such as rope tackle or pneumatic hoist, each of which renders efficient service for removing jammed blocks. With such equipment delays of one-half to three-quarters of an hour by the employment of old-time methods may be reduced to delays of two or three minutes' duration only.

SAFEGUARDS AGAINST SICKNESS AND ACCIDENT.

NEED OF SAFEGUARDS.

More and more the fact has been emphasized that man power will win the war. Hence everyone whose work contributes to the success of an essential industry should consider himself a part of the war machine. Quarrymen who provide rock necessary for military purposes are helping to win the war, and, if for any cause, such quarrymen cease work, others must take their places or the military program will suffer. When, therefore, through sickness or accident, such workers are incapacitated for service, there is a loss of man power. The accident or illness may appear to be unavoidable and then the finding of a remedy may be difficult. But if sickness or accident is through preventable causes, steps should be taken immediately to establish safe and sanitary conditions. Unnecessary wastage of man power robs the country of service at a time when the effort of every individual is most needed.

Quarry industries now suffer from a shortage of labor. The action of the United States Employment Service of the Department of Labor in allocating unskilled labor to essential industries is of great assistance, but does not relieve quarrymen of the responsibility of conserving labor to the utmost, for the supply is not equal to the demand. Moreover, such allocation does not apply to skilled labor and, therefore, no provision is made for replacing skilled quarrymen who become sick or are disabled. Thus, every loss of a workman, particularly of a skilled man, renders the labor situation more acute.

RESPONSIBILITY OF THE EMPLOYER.

A quarry operator has before him the plain duty of taking active measures to provide for the safety and health of his employees; at present those operators who provide products of military neces-

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sity have the additional responsibility of conserving man power that is of vital importance to the welfare of the Nation.

The operator is responsible for the inspection of equipment and for whatever repair is necessary to insure safety. It is his duty also to establish wise safety rules and to insist on their rigid enforcement. Provision should be made for proper sanitation as well as for all other matters pertaining to the health of employees, and for proper care of those suffering from illness or accident, in order that they may speedily return to active service.

RESPONSIBILITY OF THE EMPLOYEE.

Any number of safety measures carefully planned by quarry operators will not free the employee of his share of responsibility. Employment of dangerous methods, failure to report observed dangers, and yielding to the temptation to "take a chance" are fruitful sources of accident. Every employee should feel that he is a cog in the machine, that his utmost service is demanded, and that his country's welfare depends, in part, on his activity. This feeling should incite him to avoid all unnecessary dangers and to preserve health and strength for the work before him.

Suggestions tending to promote the safety and efficiency of quarry operators and employees have been incorporated in various publications issued by the Bureau of Mines and available for free distribution. Every quarryman should obtain a copy of Technical Paper 111[a] of the Bureau of Mines and should endeavor to put into practice the rules and suggestions printed therein. Other publications of the bureau dealing with safety problems in quarrying are Bulletin 80, "A primer on explosives for metal mines and quarrymen," by C. E. Munroe and Clarence Hall; Technical Paper 18, "Magazines and thaw houses for explosives," by Clarence Hall and S. P. Howell; Miners' Circular 11, "Accidents from mine cars and locomotives," by L. M. Jones; Miners' Circular 13, "Safety in tunneling," by D. W. Brunton and J. A. Davis; Miners' Circular 17, "Accidents from falls of rock or ore," by Edwin Higgins.

Faulty equipment, insanitary surroundings, or carlessness may reduce the effective personnel of a quarry materially through accident or disease. On the other hand, if the quarry equipment is kept in a safe condition, if healthful surroundings are maintained, and if due watchfulness is exercised in quarry operations, both operators and employees may feel that they are doing their full share in conserving the man power of the Nation.

[a] Bowles, Oliver, Safety in stone quarrying, Tech. Paper 111, Bureau of Mines, 1915, 48 pp.

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PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

BULLETIN 64. The titaniferous iron ores in the United States; their composition and economic value, by J. T. Singewalde, jr. 1913. 145 pp., 16 pls., 3 figs.

BULLETIN 70. A preliminary report on uranium, radium, and vanadium, by R. B. Moore and K. L. Kithil. 1913. 100 pp., 2 pls., 2 figs.

BULLETIN 73. Brass-furnace practice in the United States, by H. W. Gillett. 1914. 298 pp., 2 pls., 23 figs.

BULLETIN 84. Metallurgical smoke, by C. H. Fulton. 1915. 94 pp., 6 pls., 15 figs.

BULLETIN 85. Analyses of mine and car samples of coal collected in the fiscal years 1911 to 1913, by A. C. Fieldner, H. I. Smith, A. H. Fay, and Samuel Sanford. 1914. 444 pp., 2 figs.

BULLETIN 92. Feldspars of the New England and Northern Appalachian States, by A. S. Watts. 1916. 180 pp., 3 pls., 22 figs.

BULLETIN 103. Mining and concentration of carnotite ores, by Karl L. Kithil and John A. Davis. 1917. 89 pp., 14 pls., 5 figs.

BULLETIN 104. Extraction and recovery of radium, uranium, and vanadium from carnotite, by C. L. Parsons, R. B. Moore, S. C. Lind, and O. C. Schaefer, 1915. 124 pp., 14 pls., 9 figs.

BULLETIN 105. The technology of marble quarrying, by Oliver Bowles. 1916. 174 pp., 12 pls., 33 figs.

BULLETIN 110. Concentration experiments with the siliceous red hematite of the Birmingham District, Alabama, by Joseph T. Singewalde, jr. 1917. 91 pp., 1 pl., 47 figs.

BULLETIN 123. Analyses of mine and car samples of coal collected in the fiscal years 1913 to 1916, by A. C. Fieldner, Howard I. Smith, J. W. Paul, and Samuel Sanford. 1918. 456 pp.

BULLETIN 124. Sandstone quarrying in the United States, by Oliver Bowles. 1917. 143 pp., 6 pls., 19 figs.

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BULLETIN 146. Technology of salt making in the United States, by W. C. Phalen. 1917. 149 pp., 24 pls., 10 figs.

TECHNICAL PAPER 8. Methods of analyzing coal and coke, by F. M. Stanton and A. C. Fieldner. 1913. 42 pp., 12 figs.

TECHNICAL PAPER 43. The effect of inert gases on inflammable gaseous mixtures, by J. K. Clement. 1913. 24 pp., 1 pl., 8 figs.

TECHNICAL PAPER 50. Metallurgical coke, by A. W. Belden. 1913. 48 pp., 1 pl., 23 figs.

TECHNICAL PAPER 76. Notes on the sampling and analysis of coal, by A. C. Fieldner. 1914. 59 pp., 6 figs.

TECHNICAL PAPER 88. The radium-uranium ratio in carnotites, by S. C. Lind and C. G. Whittemore. 1915. 29 pp., 1 pl., 4 figs.

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TECHNICAL PAPER 111. Safety in stone quarrying, by Oliver Bowles. 1915. 48 pp., 5 pls., 4 figs.

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TECHNICAL PAPER 187. Slag viscosity tables for blast-furnace work, by A. L. Feild and P. H. Royster. 1917. 38 pp., 1 fig.

TECHNICAL PAPER 198. Sulphur dioxide method for determining copper minerals in partly oxidized ores, by Chas. E. van Barneveld and Edmund S. Leaver. 1918. 14 pp.

PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS.

BULLETIN 11. The purchase of coal by the Government under specifications, with analyses of coal delivered for the fiscal year 1908–9, by G. S. Pope. 1910. 80 pp. 10 cents.

BULLETIN 12. Apparatus and methods for the sampling and analysis of furnace gases, by J. C. W. Frazer and E. J. Hoffman. 1911. 22 pp., 6 figs. 5 cents.

BULLETIN 22. Analyses of coals in the United States, with descriptions of mine and field samples collected between July 1, 1904, and June 30, 1910, by N. W. Lord, with chapters by J. A. Holmes, F. M. Stanton, A. C. Fieldner, and Samuel Sanford, 1912. Part I, Analyses, pp. 1–321; Part II, descriptions of samples, pp. 321–1, 129. 85 cents.

BULLETIN 29. The effect of oxygen in coal, by David White. 80 pp., 3 pls. 20 cents.

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BULLETIN 38. The origin of coal, by David White and Reinhardt Thiessen, with a chapter on the formation of peat, by C. A. Davis. 1913. 390 pp., 54 pls. 80 cents.

BULLETIN 41. Government coal purchases under specifications, with analyses for the fiscal year 1909–10, by G. S. Pope, with a chapter on the fuel-inspection laboratory of the Bureau of Mines, by J. D. Davis. 1912. 97 pp., 3 pls., 9 figs. 15 cents.

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